Development of a Low-cost UAV System for Civilian Airspace Integration Trials

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Summary: This paper provides an overview of the Queensland University of Technology Uninhabited Airborne Vehicle (QUAV) Project. The undergraduate student project focuses on the development of a low-cost UAV for civilian airspace integration trials and as a test-platform for research being conducted by the Airborne Avionics Research Group (AARG).This paper presents an overview of the avionics architecture and airworthiness framework developed and provides a discussion on the challenges to low-cost UAV development. Results from flight testing and the implementation of the airworthiness framework are presented as are design experiences such as the shift to Real-time Operating Systems (RTOS) and utilisation of Commercial Off-The-Shelf (COTS) components for rapid prototyping.

Keywords: Unmanned Vehicle, UAV, UAV Development, Airworthiness Framework, Civilian Airspace Integration, Civilian Airspace Flight Trials

Introduction

The QUAV Project is primarily an undergraduate program focussing on the development of UAV technologies.

The primary objective of the QUAV Project is the development of UAV research and development platform. The UAV will be used as a test-bed for advanced UAV concepts currently being researched by the Airborne Avionics Research Group (AARG). It is envisaged that the current platform, called QUAV-3, will eventually be used for civilian airspace integration trials. The QUAV-3 platform, pictured in Fig. 1, has the basic functionality necessary for flight trials including: a real-time command and control link, Mode A/C transponder for visibility to Air Traffic Control (ATC) and the foundations of an airworthiness framework to explore certification and operations in Australian airspace.

The QUAV project also serves as a valuable teaching and learning tool for undergraduate aerospace avionics engineering students. The project provides students with experience in UAV development and operational procedures at the grass roots level.

Fig. 1: QUAV-3 Research and Development Platform

Background

Since 1991, QUT has been developing cost-effective avionics technologies as a practical teaching and learning exercise for undergraduate Aerospace Avionics Engineering students. The program has grown and has since specialised in the research and development of UAVs.

QUAV-3 is a 1/3-scale model of a Piper Cub and has been the primary platform under development since 1999. The Piper Cub platform was selected for its stability and large payload capacity.

The project operates on limited resources and subsequently cost is a major consideration in the design and operation of the platform. The project endeavours to utilise legacy assets, both software and hardware, to speed up development and to reduce costs. The use of legacy equipment has seen a high level of maturity develop in systems such as the Common Computing Platforms (CCPs) and the flight management and sensor interface software modules.

The project team changes annually, with the exception of students continuing on with postgraduate research as a part of the AARG. Despite extensive documentation a significant amount of knowledge and experience is lost in the transition between years. This is one of the challenges to ongoing development and the continuity of project.

The QUAV-3 platform has evolved over a number of years. In 2002, an avionics architecture was designed and integrated, however during field testing it was noted that there was a drastic reduction in the effective range of the hobby-grade Remote Control (RC) system used to control the UAV for take-off and landing. This was due to the lack of electromagnetic compatibility (EMC) between the RC system receiver and the CCPs onboard the UAV.

The primary objective of the 2003 project was to investigate the electromagnetic environment onboard the UAV and implement measures to resolve the EMC issue between the CCPs and the RC receiver. Despite the implementation of a number of electromagnetic interference (EMI) reduction and mitigation measures, the 2003 project failed to completely resolve the EMC problems to an airworthy standard [1]. 2003 also saw the shift of the onboard processing to a Real-Time Operating System (RTOS) on a PC-104 small form-factor computer. However, in the rush to complete the onboard system for flight testing and due to inappropriate test procedures, the PC-104 computer was damaged and could not be replaced before the completion of the semester. This brought an end to project development in 2003.

The 2004 project team proposed an architecture which removed the RC system receiver from the onboard systems to resolve the issue of EMC. The donation of a transponder from Microair Avionics, and the events of the previous year identified a need for an airworthiness framework to provide a level of control in all aspects of the project and to facilitate operations in Australian airspace. The avionics architecture and airworthiness framework developed are discussed further in the following section.

Design and Development

The 2004 QUAV-3 project is unique in that it not only focuses on the technical development of a UAV but also the establishment of an airworthiness framework which facilitates the certification of the UAV for operations in Australian Airspace.

QUAV-3 Avionics Architecture

The completed avionics architecture facilitates operation of the UAV in an autonomous mode. The architecture can be broken into two systems, a ground component and airborne component. Communications between the two systems are via spread spectrum Industrial, Scientific and Medical (ISM) band radio modems, as shown in Fig. 2. The use of this equipment for a vital (safety of flight) application requires consideration of several important factors which are discussed in the following section.

[w1]

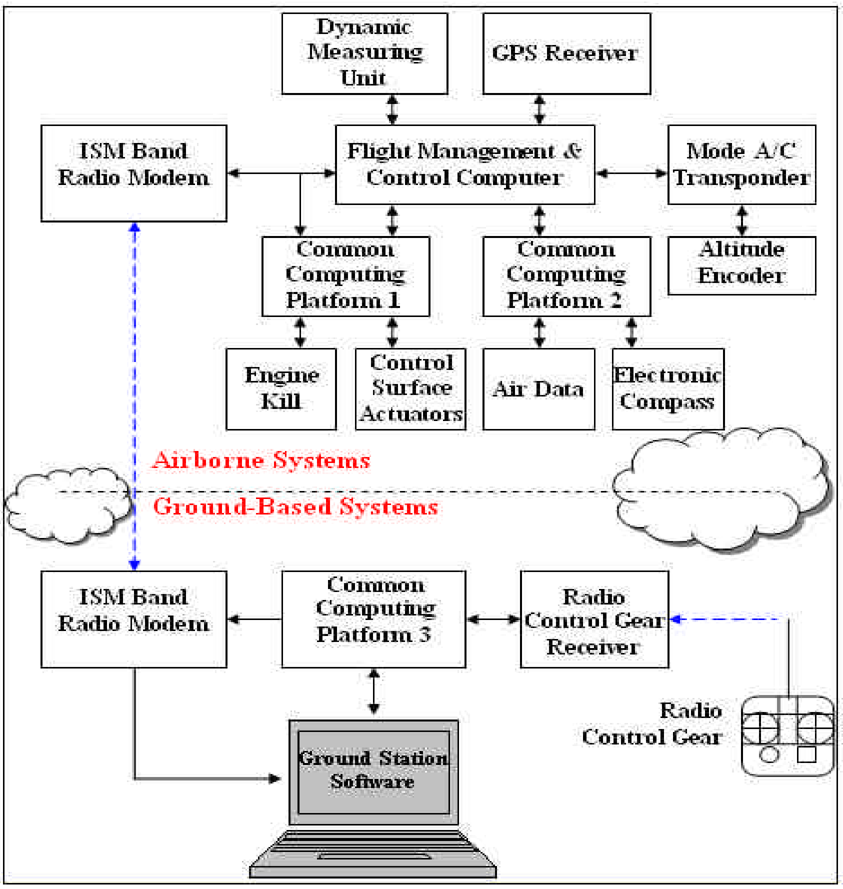


Fig. 2: QUAV-3 Avionics Architecture

The core of the onboard systems is the Flight Management and Control System (FMCS). The FMCS interfaces to the Crossbow Dynamic Measuring Unit (DMU), Global Positioning System (GPS) receiver and mode A/C transponder. The FMCS performs a number of functions:

- Handles high-level hardware communications with sensors[w2] and peripherals including the transponder, DMU, GPS, radio modem and two CCPs. See Fig 2.
- Provides real-time data logging of attitude (DMU) data, GPS position solution, altitude, transponder state and control surface deflection commands made by the UAV operator and/or onboard control system
- Onboard determination of the state vector (three components of position and three components of velocity) from available sensor data
- Performs flight control calculations to determine guidance commands to achieve mission objective eg: waypoint or heading
- Mission planning and management for dynamic waypoint by waypoint missions
- Can be expanded to include an intelligent mission planner and piloting component for complex airspace environments
- Acknowledgement and servicing of commands made by the UAV operator
- Health monitoring of onboard systems
- Telemetry downlink of data to provide the operator with an awareness of the UAV

In previous architectures the UAV Flight Management and Control Program (FMCP) was implemented on multiple CCPs running a quasi-operating system environment. The low processing power of the CCPs severely limited the functionality available onboard the UAV. The 2004 architecture replaces the CCPs with a PC-104 small form-factor personal computer. The PC-104 has a 486DX-66 MHz processor with 32MB of RAM, six serial communications ports and 512 MB of flash storage media.

Previous avionics architectures had utilised a system databus based on a Controller Area Network (CAN) and subsequently, all modules were specified to be CAN capable. However, in the present architecture, all communications are via RS-232 serial communications for three reasons: firstly, all of the COTS peripherals had some form of existing serial communications interface capability, serial communications offer a simple solution in both hardware and software, and finally a common interface reduces development time, costs and interface issues. It was not considered cost effective to convert all of these systems to CAN, as the benefit gained was not warranted. However, the limitations of point to point serial communications are obvious, and future developments will no doubt utilise a databus, potentially based on TCP/IP, to facilitate further system functionality.

As stated earlier, previous architectures used multiple CCPs running a quasi-operating system environment. Late 2003 saw the shift of onboard processing to a PC-104 running the QNX® Neutrino® Real Time Operating System (RTOS). The RTOS provided a robust and reliable platform to base the FMCP and the advantages of this are discussed in the following section. A customised boot image was built for the PC-104 computer which removed unnecessary components of the operating system, speeding up boot time and reducing operating system overheads. The power of this new hardware and software was fully utilised with an implementation of the ISIS[w3] UAV executive system which has been in development in the AARG over the past few years at a post-graduate level [2]. ISIS is a module of the Intelligent Aircraft System (IAS) developed by the AARG. Designed specifically for use on a RTOS, ISIS provides the foundation for the FMCP.

The final component to the onboard system is the mode A/C transponder and altitude encoder. The T2000UAV mode A/C transponder kindly donated by Microair Avionics is built specifically for UAV applications but is based on their certified T2000 aircraft transponder. The FMCP handles communications with the transponder. A software module residing on the ground station mission planning and telemetry display program provides a user interface for transponder control. A barometric altitude encoder interfaces directly to the transponder and provides a supplementary[DG4] measurement of altitude onboard the UAV.

The ground station system architecture consists of a CCP and a Personal Computer (PC) running Microsoft Windows XP operating system and a custom designed UAV telemetry and control program. During the Remotely Piloted Vehicle (RPV) phase of flight (eg: taxi, take-off, emergency or landing), the CCP receives commands from the RC receiver and transmits this information via the radio modems to the onboard system. The CCP also routes operator commands from the Ground Station PC to the airborne segment. The ground station PC hosts the mission planning and telemetry display program. This program provides the UAV operator with an awareness of the UAV status and a means for uploading commands. The program currently includes simulated cockpit instruments including an artificial horizon and compass, a full moving map display utilising Australian Aeronautical Information Publication (AIP) charts, transponder command interface and system health status display. Fig. 3 shows a screenshot of the UAV mission planning and telemetry display program operating on the ground station PC.

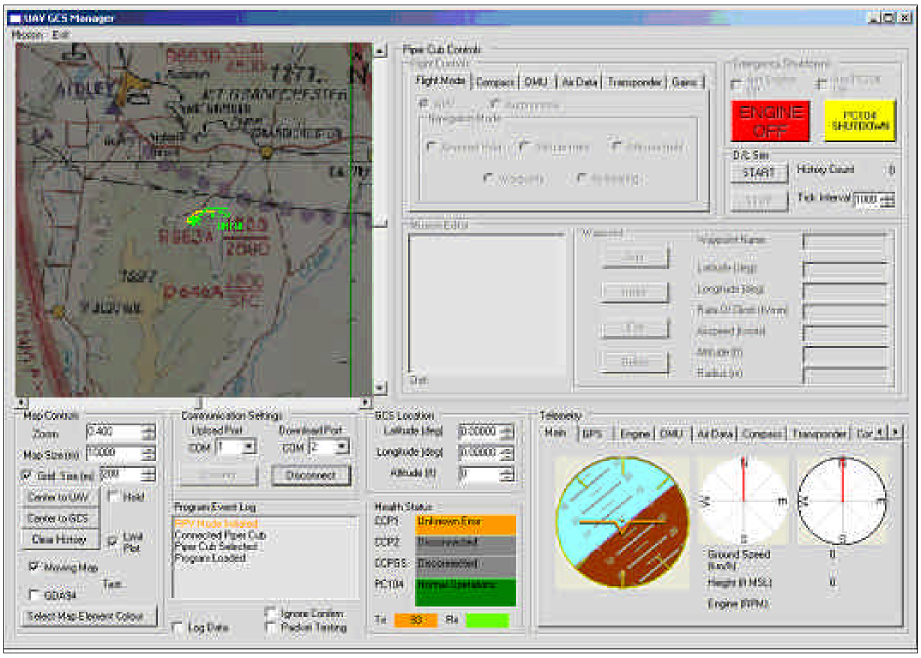


Fig. 3: Ground Station mission planning and telemetry display

QUAV-3 Airworthiness Framework

The ownership of a UAV capability is more than just the design and possession of the physical vehicle. As any aircraft owner would know; safe operation and ownership is governed by an airworthiness framework established and enforced by regulatory bodies. The Australian Civil Aviation Safety Authority (CASA) was the first national authority to develop regulations specifically for the operation of UAVs. Civil Aviation Safety Regulation 1998 (CASR or CAR 1998) Part 101 implements regulations allowing the operation of a UAV in

Australian civilian airspace. The QUAV project team worked closely with the CASA, Air Services Australia (ASA), airfield owners and the University's insurance company to establish an airworthiness framework in accordance with the requirements of CASR 101. This framework has seen the QUAV Project become the first in Queensland to receive area approval for the operation of UAVs, See Fig. 4 below.

Australian Government

Civil Aviation Safety Authority

INSTRUMENT NUMBER RSBFO-04/084

CIVIL AVIATION ACT 1988

CIVIL AVIATION SAFETY REGULATIONS 1998(CASR)

APPROVAL OF AREA FOR THE OPERATION OF UNMANNED AIRCRAFT

I, Gregory Philip Bath, a delegate of CASA, under regulation 101.030(1)(a) of the *Civil Aviation Safety Regulations 1998* (CASR), having taken into account all relevant considerations relating to the interest of safety, approve the following area:

- An area described by a two nautical mile radius around Bubbling Springs airfield (Latitude South 27 Degrees 41.172 Minutes, Longitude East 152 Degrees 25.453 Minutes) from the surface to 2,500 ft AMSL

for Unmanned Aerial Vehicle (UAV) flight operations conducted by Dr Rodney A Walker as part of the Queensland University of Technology Unmanned Aerial Vehicle (QUAV) Project. [w5]

Fig. 4: Excerpt of CASA Area Approval for the QUAV-3 Project

The airworthiness framework established by the QUAV-3 Project addresses the need for controlled procedures in design, manufacture, maintenance and operation to ensure the safe operation of a UAV capability in accordance with all regulatory requirements.

The airworthiness documentation system included:

- An Engineering Management System (EMS) which defines the QUT organisation, people, processes and data management activities in support of the QUAV Piper Cub to provide design control.
- Technical Maintenance System (TMS) which defines the maintenance policies for the QUAV-3 test platform.
- Operational Management System (OMS) which details organisational activities in the operation of the UAV. This includes organisational interfaces, authorisation procedures, documentation and airfield management.
- Airworthiness Instructions (AI) which are a series of documents to direct the conduct of a flight test and to ensure all phases of the flight test activity will be conducted safely, accurately and in a controlled way to ensure success of this important flight test activity.

Test Results

The avionics architecture underwent an intense regime of testing. A test philosophy was written for each sub-system, with all design requirements clearly traceable to individual test procedures. Testing followed a white, grey, black box test methodology [3]. As will be shown, many design issues were identified through a rigorous testing philosophy and they highlight the importance of such procedures in a robust design process.

Testing Methodology

Testing was first conducted in the laboratory with sub-system components undergoing low-level/white box [w6]testing [3]. Software was tested at the module level and the results from all tests were thoroughly documented. As each component of a sub-system was verified, testing would move to the interfacing of sub-system components and finally the functionality testing of a completed sub-system. This testing process continued and was completed with the validation of the UAV system in a series of field tests culminating in a number of successful Remotely Piloted Vehicle (RPV) flight tests. Despite the successful flights, a number of design issues were revealed during field testing, and are discussed below.

Dynamic Measuring Unit Problems and Resolution

One issue was the mounting of the Dynamic Measuring Unit (DMU). The DMU is used to determine the attitude of the UAV by providing aircraft pitch and roll angles, and angular rates and accelerations about the roll, pitch and yaw axes. It is capable of providing highly accurate measurements at a high bandwidth; however the accuracy of these measurements is dependent on aircraft manoeuvres, gyro drift, temperature and vibration.

The QUAV-3 is powered by a 62cc 2-stroke engine, operating between 2000-9000 rpm. The vibration from the engine greatly reduces the reliability of the DMU data. As the project had no control over the internal filtering algorithms used to produce attitude estimates, the only means available to improve data reliability was in the design of the DMU mounting. The initial mounting design did not take into consideration this intense vibration as all prior testing had been conducted in the laboratory. The DMU data logged during ground testing revealed that the original rigid mounting directly to the avionics stack did not provide sufficient isolation from the engine vibration and subsequently the DMU data was too corrupted for use by the onboard attitude controllers. A new DMU mounting system was required.

The new mounting arrangement, pictured in Fig. 5, had no rigid connection between the DMU and avionics stack. Another advantage of the new mounting system was that the dampening characteristics could be varied by changing the thickness of shock-absorbing foam blocks. Stationary ground tests were carried out to assess the effectiveness of the new mounting system. A disadvantage of the devised mounting system was a larger alignment error which tended to vary from flight to flight since the mounting system did not always return to the same position.

During the test the engine was cycled between idle and full throttle. Fig. 6 shows three plots of the DMU pitch angle measurement as a function of system time for three different mounting configurations. The ideal measurement would be a constant angle without the high frequency component due to the engine. Test 1 shows the results for a semi-rigid mounting, test 2 with very little rigidity in mounting and test 3 for medium rigidity. The plots show that a semi-rigid mounting (test 1) provides improved DMU isolation over the other two mounting configurations. This test is far from conclusive and indicates one of the fundamental UAV problems, namely the location and mounting of sensitive attitude sensors on a small platform with high vibration propulsion system. Further investigation will determine the effect of DMU mounting location on the errors.

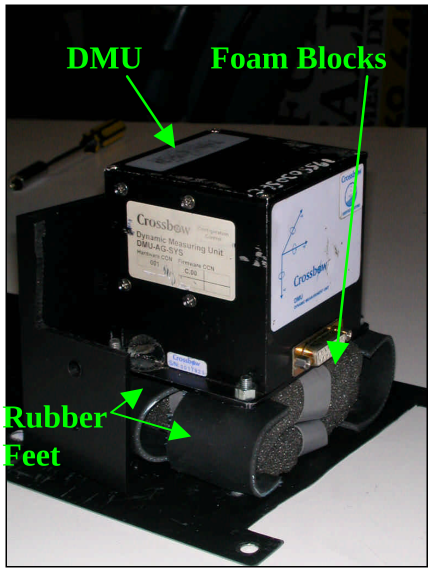
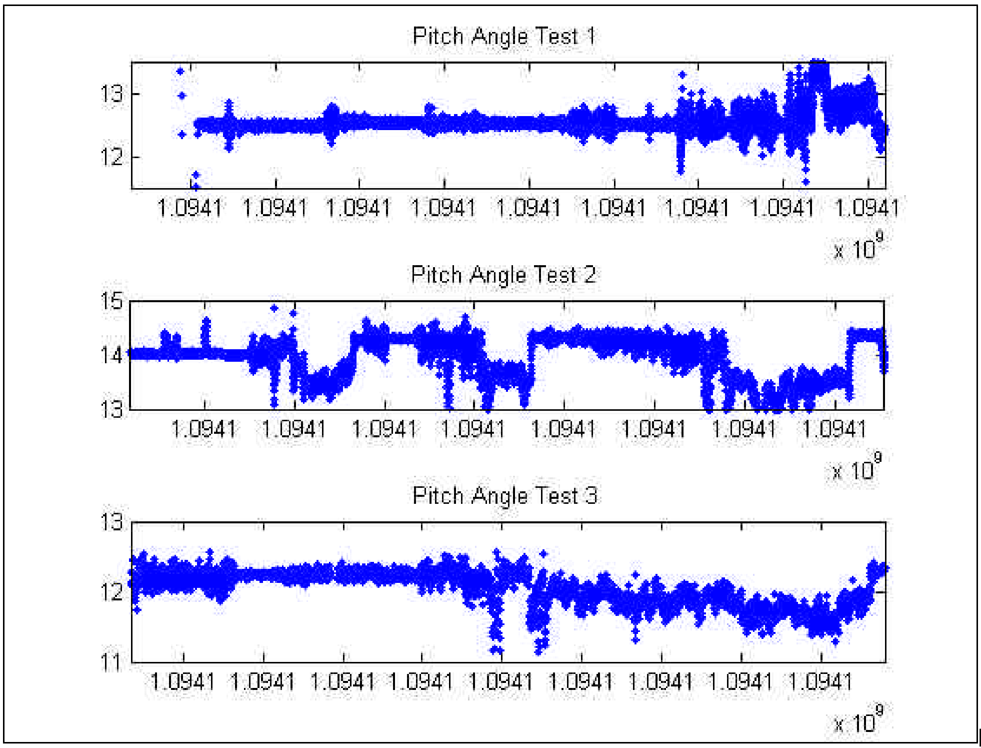


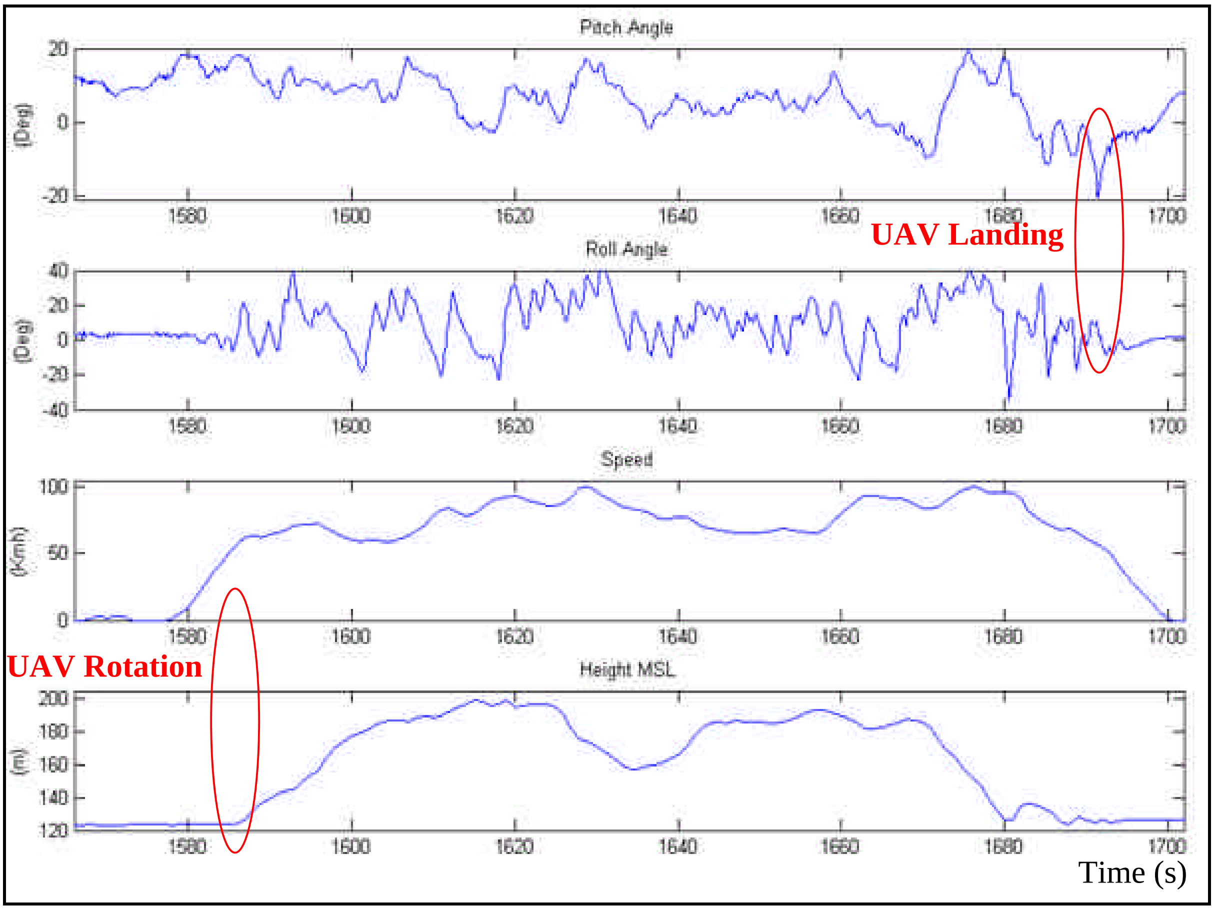
Fig. 5: DMU Experimental Mounting



[w7]

Fig. 6: Pitch angle plots for different mounting configurations

Results recorded from flight testing, see Fig. 7, were more promising. The plots show pitch and roll angle recorded by the DMU for a two minute flight test using the same semi-rigid mounting. The engine was operated at all throttle settings during the test. Noise due to the engine is still present and is substantially less than that in ground testing, as expected, however there was still poor correlation between angle data measurements when compared with estimates based on video footage taken during the flight. The large pitch and roll fluctuations seen in the measured data were not apparent in the flight video.



[w8]

Fig. 7: DMU Pitch and Roll angle measurements for a two minute flight test

Analysis was then conducted on the correlation between control surface deflections and measured rate data. The hypothesis was that an input of aileron or elevator command should result in a roll or pitch rate, with some lag. Fig. 8 shows the good correlation between these two signals; however of interest is the bias evident in the roll rate measurement. This may be due to filtering error caused by vibration, an aircraft out of trim condition, or a combination of the two.

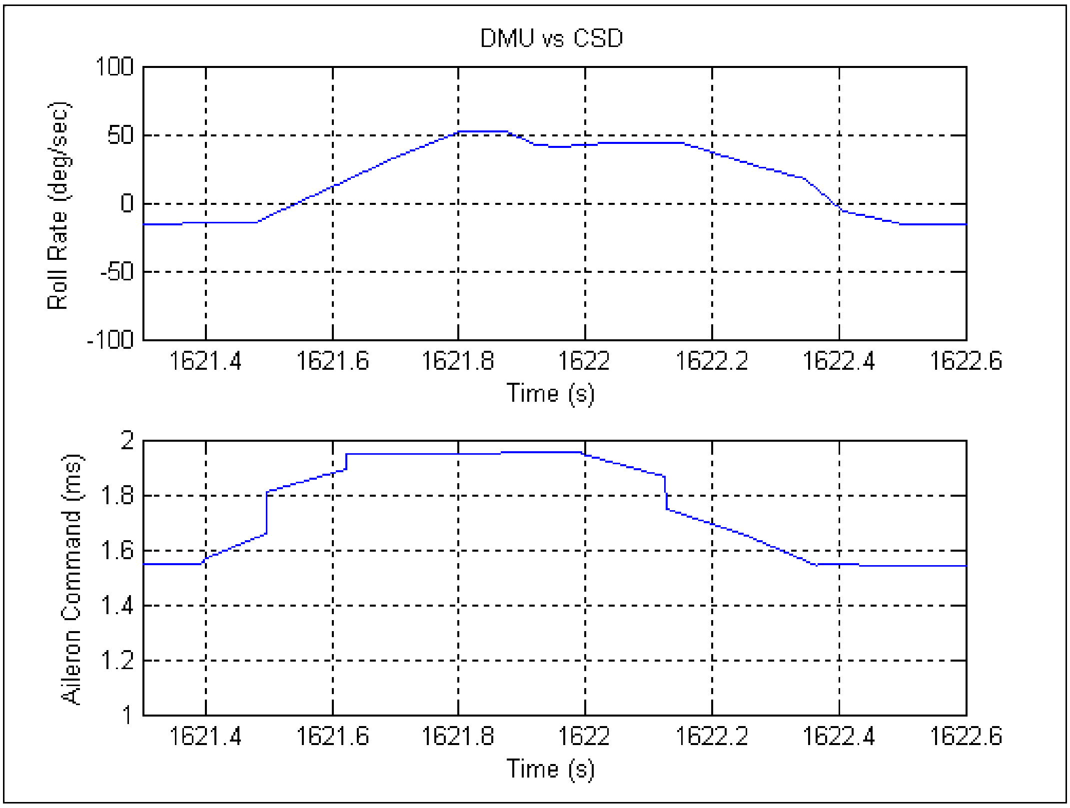


Fig. 8: Measured Roll Rate and Aileron Input[1]

Communications to the Crossbow DMU are via serial RS-232 standard communications, with a logging data rate of 50Hz. The DMU was unnecessarily complicated to calibrate. If initialisation of the DMU did not occur within a certain time of powering on, it would "lock up" and not respond to commands. A comprehensive QNX software library was developed to handle communications with the DMU [4], however care still needed to be exercised by the user to ensure reliable operations.

Radio Data Link Considerations

The use of COTS components provided other design issues, in particular the 905U-D Direct Sequence Spread-Spectrum (DSSS) radio modems manufactured by ELPRO Technologies. The radio modems were a legacy asset and provide the sole communications link to the UAV. There were two fundamental considerations in the use of these units in this application. The first consideration is in maintaining adequate noise margin to ensure good data link performance, and the second is arbitration of critical uplink verses telemetry downlink data through the half duplex link.

Uplink and Downlink Data Arbitration

During ground testing the UAV operator noted a significant amount of lag between the control surface commands made using the Radio Control (RC) gear and the physical movement of control surface actuators onboard the UAV. The handling qualities of the UAV were significantly degraded due to the lag and the safe operation of the UAV in RPV mode

[1] Note: The Aileron Command refers to a timing signal that is passed to the control surface actuator, and subsequently results in an angular control surface deflection.

was not possible. This lag was attributed to the radio link between the ground and air systems.

The lag presented an interesting trade-off between UAV handling and operator awareness at the ground station. In RPV phases of flight, uplink is primarily control surface data from the RC gear and downlink is a 1Hz periodic telemetry data stream. Increasing the baud rate of the radio modems, in combination with reducing the amount and frequency of telemetry data would be a solution to this problem. However the higher baud rate would increase the Bit Error Rate (BER) and reduce the maximum Line Of Sight (LOS) range. Reducing the telemetry data stream and frequency of downlink would reduce operator awareness of the UAV at the ground station. As the procurement of a full duplex radio transceiver was beyond the resources of the project a number of investigations were carried out.

The final solution came through an increase in radio transmission baud rate from 19200 bps to 57600 bps whilst keeping the data transmission baud at 19200 bps, reducing the radio transmission packet length, and a reduction in the amount of telemetry data being transmitted. The telemetry downlink rate remained at 1 Hz. The estimated reduction in LOS range due to the increase in baud rate was 40% with the worst case maximum range reduced from 15 km to 9 km, based on one way radio range equation estimates, and OEM advice. The current flight plans are conducted within visual range of the ground station, typically less than 1 km, and within the approved operational area of approximately 2 km radius of the airfield. Therefore the reduction in range does not impact on the safe operation of the UAV within the pre-defined area of operations. With these modifications and after a series of ground tests, the UAV was flown in a RPV mode. The UAV Controller verified that the QUAV-3 responded safely to pilot commands with the new uplink structure.

Noise Measurements

In order to ensure that a good uplink signal would be received at the aircraft throughout flight testing, a number of tests were conducted to measure the background noise level at the flight test location, and to also measure the received signal strength at the aircraft in flight configuration. Fig. 9 shows the results of these tests, which utilised in built functions of the radio modems.

The green line is the measured mean background noise level at the test site. The raw data (blue line) was measured by walking the aircraft along the length of the runway and back whilst the ground station transmitted data. It was considered that the aircraft at ground level would represent a worst case scenario of received signal performance. At approximately 800 [w9]seconds (point ***B*** in Fig. 9) into the test, the aircraft was turned around and returned to the ground station location, which was accompanied by a 10dB worsening of received signal strength. This is attributed to the fact that during this phase of the test, the ground plane of the aircraft was between the transmitting antenna and the ground station. The low received signal [w10]at the beginning and end (Points ***A*** and ***C*** respectively) of the test is relatively inconclusive, however a consideration is the fact that the ramp operations for the UAV were conducted at a lower point than the ground station, and the aircraft and ground station equipment blocked line of sight between the two antennas.

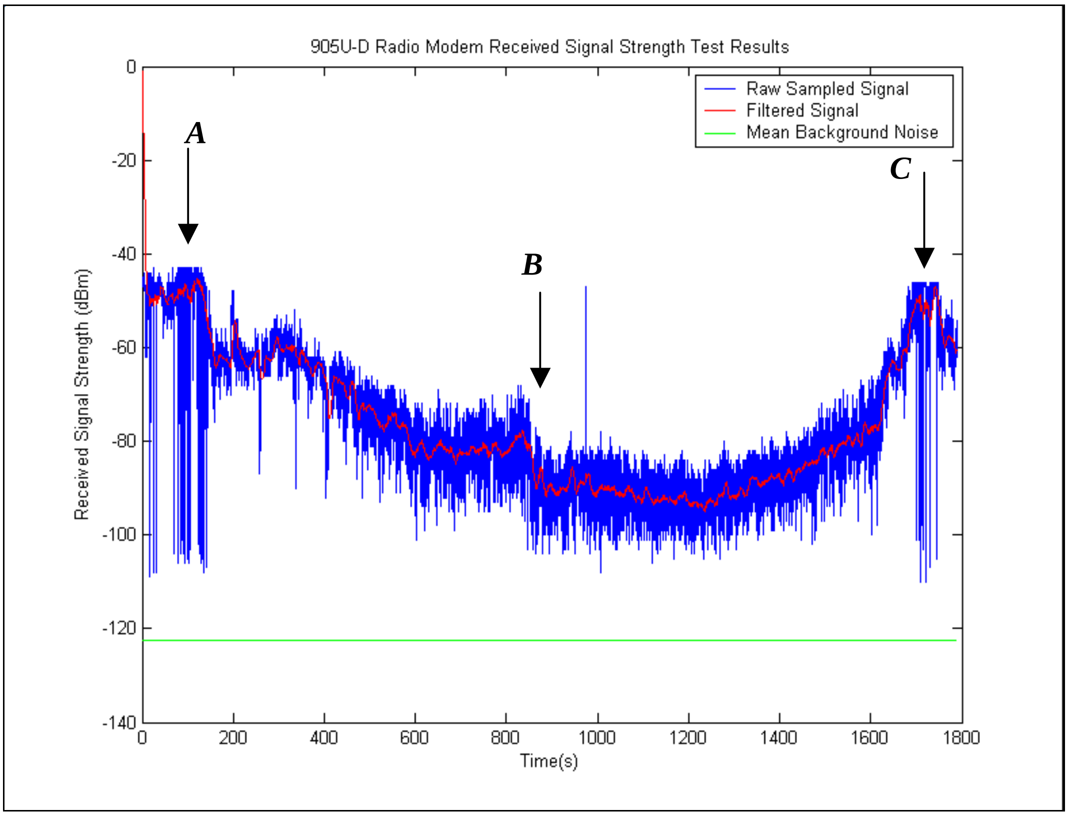


Fig. 9: Radio Modem Signal Strength Test Results

It is not possible to repeat these tests for flight validation of datalink performance. This is due to the avionics architecture configuration. The risk that the radio modem ground tests did not sufficiently represent link performance for airborne operations was significant and one that was considered during the operational planning of the flight tests. The risk was ultimately considered acceptable given the testing that was conducted, and the other precautions taken during testing.

Overall, good noise margin was found to exist throughout this test, and successful flight testing validated the previous assumptions for local area operations.

Software Problems

During testing of the onboard power system an unusual event was observed. The test was to determine the maximum safe operation time for the 12V avionics supply, using actual flight hardware in order to validate the Electrical Load Analysis (ELA) prediction. The voltage and current plot is shown in Fig. 10.

Approximately 45 minutes into the test there was a sudden drop in current draw from the avionics load. The test was repeated and the event was again observed approximately 45 minutes into operation. The test was carried out in the laboratory so temperature was not thought an issue. The supply voltage was still above 12V; with most onboard devices capable of operating on as low as 9-10V there was no immediate explanation for the drop in current draw.

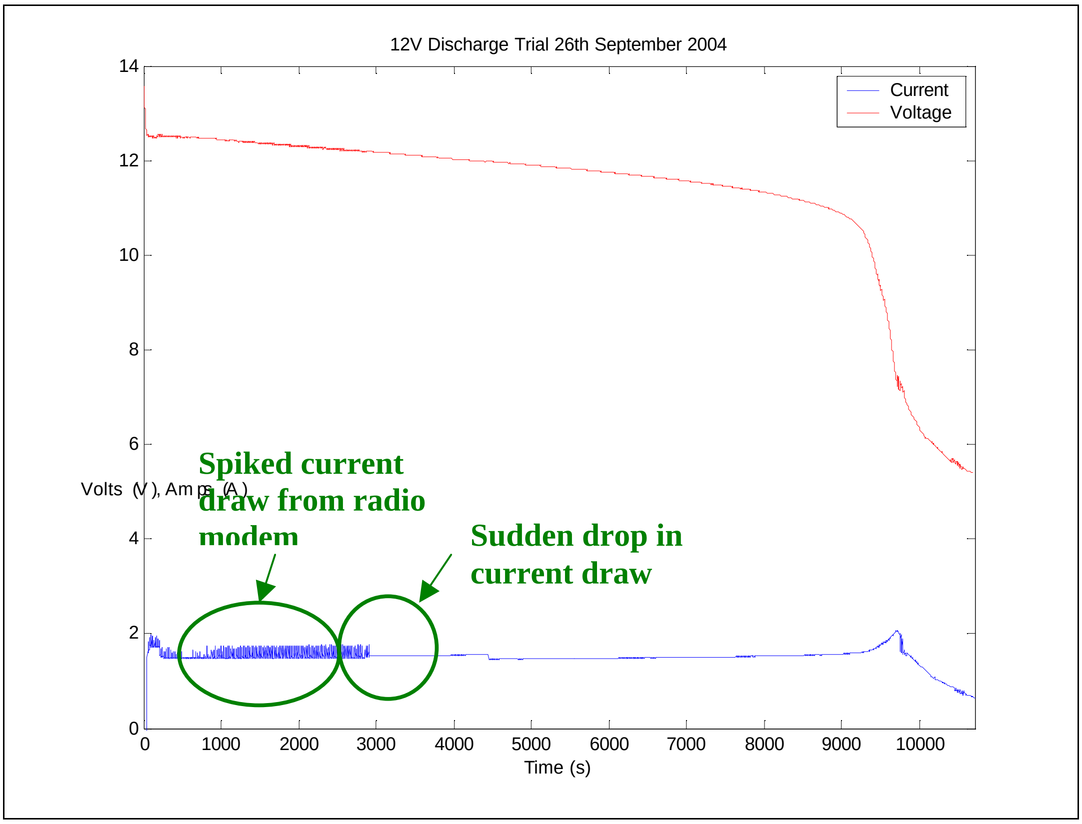


Fig. 10: Power System Test

The spikes in current draw [w13]seen during the first 45 minutes of the test are caused by the telemetry downlink transmission, and when these stop, it highlighted a problem with the Management and Control Program (FMCP). An extended duration test of the Flight Management and Control Computer (FMCC) with the FMCP running confirmed that the FMCP was terminating approximately 45 minutes into operation. The FMCC was still running (an advantage of RTOS) but the FMCP processes had been terminated. The bug was soon traced to dynamic memory allocation which, without proper calls to free the memory, grew each time the thread was called. The internal software partitioning of the ISIS system, plus the protected memory space of the QNX RTOS architecture prevented the OS from crashing but terminated the offending processes, ensuring that the failure did not spread to other parts of the system.

Flight Test Results

During the four flight test serials conducted, the top speed reached was higher than expected, and resulted in adjustments to the failsafe mechanisms installed in the UAV to ensure it did not fly away in the event of a failure.
One problem noted in using GPS data is the 1Hz position update rate provided by the GPS positioning sensor was not adequate to maintain good situational awareness in the local area, especially when coupled with lags associated with the downlink and ground station PC display process.

A severe limitation of the ground station PC was its lack of real time performance in displaying flight data, which severely degrades the reliability of the system. This has prompted a move to use of the QNX RTOS in the ground station PC system, which should lead to several advantages which have already been utilised by the airside component.

Design Experiences

The combination of increased processing power and the shift to a real time operating system provided many advantages. Firstly the increased processing power drastically increased the level of functionality and capability of the onboard systems. One processor replaced the functionality of multiple CCPs, reducing weight and complexity. The modular nature of the PC-104 facilitates easy expansion with COTS add-on cards available, including Controller Area Network (CAN) and serial port cards. The PC-104 includes a 100Base-T ethernet controller which provides an additional communications bus, means for remote access and quick software development.

A prime example of the benefits for COTS components is the add-on serial port card for the PC-104. The card was made functional within the architecture in a matter of hours, whereas the same activity for the CCPs took more than a month, when taking into account the design, manufacture and testing of the hardware and software components.

The shift to the QNX® Neutrino® RTOS provided a robust, reliable and scalable software platform from which to run the FMCP. A RTOS offers many benefits over a Non-Real-time Operating System (NROS). A RTOS concentrates on consistent and predictable timing. This allows time critical processes such as the calculation of control surface deflections or data logging to be performed with a precisely known tolerance. An additional benefit, derived from the architecture of the RTOS, is stability. The stability of the operating system is an important aspect for any autonomous vehicle; an operating system crash mid-flight would constitute a safety critical failure and would result in the loss of the UAV.

The utilisation of the Momentics® Integrated Development Environment (IDE) greatly simplified the software development. The Momentics® IDE offers code development, target upload, target monitoring and debug functionalities in a single application. The IDE proved very useful in identifying timing and memory issues within the FMCP. Communications to the target system can be over Ethernet or serial communications port. The use of the Momentics® IDE greatly reduced development time.

The practical application of the airworthiness framework has seen continual improvements to the operational management system and airworthiness instructions. Maturity of the framework will continue to grow through its practical application to the QUAV-3 project.

Maintenance control generally ran smoothly. A careful balance was struck between efficiency and design control in order to a) maintain the systems airworthiness and b) ensure that time is not wasted in unnecessary documentation, especially with a student workforce which would move on each year. It was considered that the maintenance and design control system operated under the airworthiness instruction system performed well in this environment. Whilst the Airworthiness instruction detailed steps to be carried out on an approved basis by the authorising officer, flexibility remained for the UAV Controller to make changes. This however did require the UAV controller to adopt the role of operator and chief engineer at once in considering decisions which affected the airworthiness of the operation.

An example of this was when it was found that the steerable tail wheel of the aircraft did not perform adequately with the increased ramp weight of the aircraft. A decision was made by the team members, and authorised by the UAV controller, to remove the tail wheel assembly, leaving only a skid remaining. This decision was validated by taxi trials of the modified system. All decisions were annotated in the running airworthiness instruction and subsequent maintenance documentation. This ensured efficiency, traceability and ultimately airworthiness of the entire operation.

The operational instruction was under constant improvement. With each flight test, personnel become more proficient in their responsibilities and the procedures outlined in the operational plan. Such procedures as maintenance release (hand-over to UAV Controller) and pre-flight inspections, Fig. 11 and Fig. 12 respectively, were carried out with proficiency. Increased proficiency of personnel identified a number of improvements that were initially overlooked by the operational instruction.

Examples of such improvements include: the absence of a DMU warm-up period in the flight instruction resulting in unusable DMU data recorded from a flight test, or the consideration of environmental factors such as temperature in the payload bay due to the lack of shade over the hard-stand area. Human factors and logistics also caused some problems which needed to be overcome.

The airworthiness framework will continue to evolve as experience gained through its practical application continues, and the results from 2004 are fed into design inputs over the coming years.

Fig. 11: Maintenance Release

Fig. 12: Pre-flight Inspection

Conclusions

The QUAV-3 Project has seen the development of a RPV flight tested UAV capable of autonomous operation. The technical development has provided valuable experience in the use of RTOS, COTS components and systems engineering design and testing methodologies under the requirements of an airworthiness framework.

The airworthiness framework established ensures any UAV capability developed by the AARG is designed, manufactured, maintained and operated in a safe manner and in accordance with all regulatory requirements. This has already seen the QUAV project receive area approval for UAV operations in Australian airspace, the first for Queensland. This framework will evolve with the project. It is envisaged that the framework will eventually reach a level of maturity that will service any QUAV platform.

The QUAV-3 Project is currently in its second design evolution of autonomous operations. With the transponder and altitude encoder successfully integrated and awaiting the completion of verification testing, the project is close to realising its main objectives.

The project has proven itself as an effective and beneficial teaching and learning exercise. Students gained valuable hands on experience in UAV design within the guidelines of an airworthiness framework; very few educational institutions offer such a unique experience.

The AARG started from small beginnings and now boasts a growing number of leading-edge researchers. Research into UAV forced landing, increased onboard intelligence and mission planning, advanced health monitoring, collision avoidance techniques and revolutionary sensors has seen the AARG grow as an Australian leader in UAV advanced technologies. The completed QUAV-3 test platform will assist the AARG with its research capabilities.

Acknowledgements

This research was supported in part by a grant of computer software from QNX Software Systems Ltd. http://www.qnx.com/, avionics equipment from Microair Avionics Pty Ltd, Bundaberg, Queensland. http://www.microair.com.au/, Airfield support from Flying Fighters, http://www.flyingfighters.com.au/, and hardware components from Textron Fastening Systems Pty Ltd, http://www.textron.com.au/. The group would like to express their appreciation of the support provided from these organisations.

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